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DRAFT

TEST PROTOCOL
FOR THE EVALUATION OF
OIL -SPILL CONTAINMENT BOOMS

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(DRAFT)

TEST PROTOCOL FOR THE EVALUATION OF

OIL-SPILL CONTAINMENT BOOMS

1. SCOPE

This protocol specifies a series of tests for oil spill containment booms. By performing tests in this standard sequence and in standard environments oil holding ability data can be generated. This data can be used for performance comparisons. The tests measure:

1) The critical tow speed for boom stability in calm water,

2) The tow speed at which a barrier will first loose contained oil,

3) The tow speed at the onset of gross loss,

4) Oil loss rate,

5) Indicative wave-stress,

6) Wave conformance in open water,

7) Boom durability.

Tests 1-5 conducted in a wave tank facility are for all oil spill containment barriers. Open water Tests 6 and 7 are for oil spill barriers that are intended for offshore use.

2. Summary of the Method

Conducting the tests with this protocol will provide a complete evaluation of an oil spill boom in terms of performance

(oil holding ability). Beginning with how fast the boom can be towed in calm water before loosing stability, through determination of oil loss rates, the protocol concludes with open water tests of booms without using oil. For some, the desire may be to evaluate boom performance in the open water without conducting tank tests. Section 6.3 discusses the presently understood relationship between a booms heave motion in waves and loss of oil holding ability.

3. Significance

Conducting this protocol will provide application data useful in contingency planning for the inland river, large lake, estuary, near shore and offshore environments. Each of these environments have water current and/or wave motion that reduce oil holding ability. These tests quantify this reduced performance.

4. Applicable Documents

4.1 ASTM Standards

D-1796 Standard of Test for Water and Sediment in Crude Oils and Fuel Oils by Centrifuge.

D-96 Tests for Water and Sediment in Crude Oil (a distillation method)

STP-341 Log-linear Viscosity Interpolation by Temperature.

D-971 Standard Test for Interfacial Tension of Oil Against Water By the Ring Method.

D-2161 Standard Method for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity or to Saybolt Furol Viscosity.

D-1983 Standard Method of Testing for Apparent Viscosity of Gear Oils at Low Temperatures Using the Brookfield Viscometer.

D-1298 Test Method for Density, Relative Density (Specific Gravity) or API Gravity of Crude Petroleum and Liquid Petroleum Products.

D-1125 Tests for Electrical Conductivity and Resistivity of Water.

5. TANK TESTS

   5.1 Apparatus

        Oil boom, 27 to 35 meters

        Wave tank

        Boom towing equipment or water recirculating pumps

Tow speed or current meter

Wave meter, electronic output

Video cameras, underwater and surface

Oil distribution system

Oil collection, skimming system

Oil recovery tanks

Test oil

Stratified fluid samplers

Sample bottles, 250-ml

Laboratory centrifuge, 980 G

Centrifuge tubes, 100-ml pear shaped

Toluene

Radio or entercom communication system

Anemmeter, 10 meters above tank

Thermometers, for air and water

Hydrometers for oil and tank water

5.1.1 The tank must have the following characteristics

Length

For test tanks where the barrier is moved through stationary
water, the test tank must be long enough to provide a steady
state tow condition for the barrier lasting at least 3 minutes
(min.) when towed at 0.2 knot (kt) greater than the first-gross-
loss tow speed.   Present state-of-the-art would require a tank

170 meters long. The minimum length requirement for test tanks which circulate the water relative to a fixed barrier to produce an effective tow speed is 125% of the apex to boom-end mooring. For the rest of this test protocol, towing the boom will be equivalent to circulating the water at the prescribed relative velocities.

Width

In order to minimize (wall) effects the test tank will be wide enough to provide clearance between the barrier ends and tank walls that equals 2.5 x barrier draft when towed in the prescribed catenary (see 5.3).

Depth

In order to minimize (bottom) effects the water depth in the tank must be at least four times the barrier draft.

Tow Speed Requirements (Water Circulation Requirements)

The test facility shall have the ability to vary the relative velocity between barrier and the water. The relative velocity shall be variable in at least 0.1-kt, or less, increments. The relative velocity of the barrier will be measurable to a precision of +/- 0.05-kt or better.

Wave Generation

The ability to generate both nearly sinusoidal and harbor chop (random sea) is required. The wave conditions are specified in Section 5.2.

Underwater Observation

There must be provision to observe oil loss occurrences from beneath the boom.

Oil Distribution

In order to distribute oil at the required rated in 5.5.2, the test facility shall have the ability to distribute oil into the barrier at a minimum of 40 cubic meters per hour. All distributed oil must be floating and encountered by the boom.

5.1.2 Test Fluids

TABLE 1 TEST FLUIDS' SPECIFICATIONS

FLUID	SALINITY	SPECIFIC GRAVITY	SURFACE TENSION (DYNES/CM) @20°	OIL TANK WATER INTER-FACIAL TENSION (DYNES/CM)	VISCOSITY cSt @ WATER TEST TEMP	BOTTOM SOLIDS & WATER (% BY VOL)
TANK WATER	5-35%	1.003-1.028		>18		
LIGHT OIL		0.88-0.93	>20	>18	10-50	<1%
HEAVY OIL		0.90-0.95	>20	>18	700-1000	<1%

5.2.3 Instrumentation

The tow speed or current meter is for the use of the tank operator and need not have electronic output for recording. However, communication between the tank operator and boom observers must be constant. The wave meter must have an electronic output for recording either on a stripchart or digitally for subsequent data manipulation. The wave meter must be precise to as little as 5-mm surface changes on waves up to 0.6 meters one third significant wave height.

5.2 Wave Conditions

Three wave conditions for tank testing are:

5.2.1 Calm Water

Surface conditions with wind produced wave heights less than 10% of the barrier freeboard is considered calm water. There will be no mechanically generated waves.

5.2.2 Breaking Sinusoidal Wave (Wave #1)

There must be evidence of white caps on the wave crests at some portion of the test tank length. Spectral analysis must show that the wave record is nearly monochromatic. The wave record will be considered monochromatic if there is a concentration of wave energy (90% of the total) over a narrow frequency band between 0.7 and 1.0-Hz.

Apparent Length

The wave will have an apparent wave length of less than 3.0-m.

One-third Significant Wave Height

The wave will have a one-third significant wave height of (H 1/3) 0.19 +/-.08-m.

Apparent Wave Period

This wave will have an apparent wave period of at least 1.0 second (s) and at most 1.5-s.

5.2.3 Harbor Chop (Wave #2)

The time required to develop a harbor chop in a wave tank is characteristic of the individual tank as are the relationships between the magnitude and periodicity of the wavemaker and the resultant harbor chop. The waves generated prior to establishing equilibrium are considered part of pretest conditions not to be used for testing.

One-third Significant Wave Height

The one-third significant wave height (H 1/3) of the harbor chop will be 0.45 +/- .08-m.

Apparent Wave Period

The wave will have an apparent period of 2.2 +/- .2 seconds.


5.3 Pretest Setup

Barrier Requirements

The barrier under test shall be at least 27 and not more than 35-m long. It will be a full-scale representative section of the barrier. It will be tested using the manufacturer's towing assembly when possible.

Set-up

Rig the boom in a catenary configuration, with the gap equal to 67% of the length. It is recommended 67% be used. The boom will be attached to the towing assembly with tethers on both ends of the barrier. The tether will be at least 1.5-m and at most 5-m long. The oil distribution system will be placed so that all the oil will enter the gap. See Figure 1.

5.4 Test

Record the ambient conditions before and during testing. These include air and water temperature (as measured with a thermometer, thermistor, or thermocouple), wind speed and direction relative to the test tank and direction of tow (as measured with a weather vane and anemometer). Since wind acts on the boom freeboard it is recommended that tests not be run if wind speed
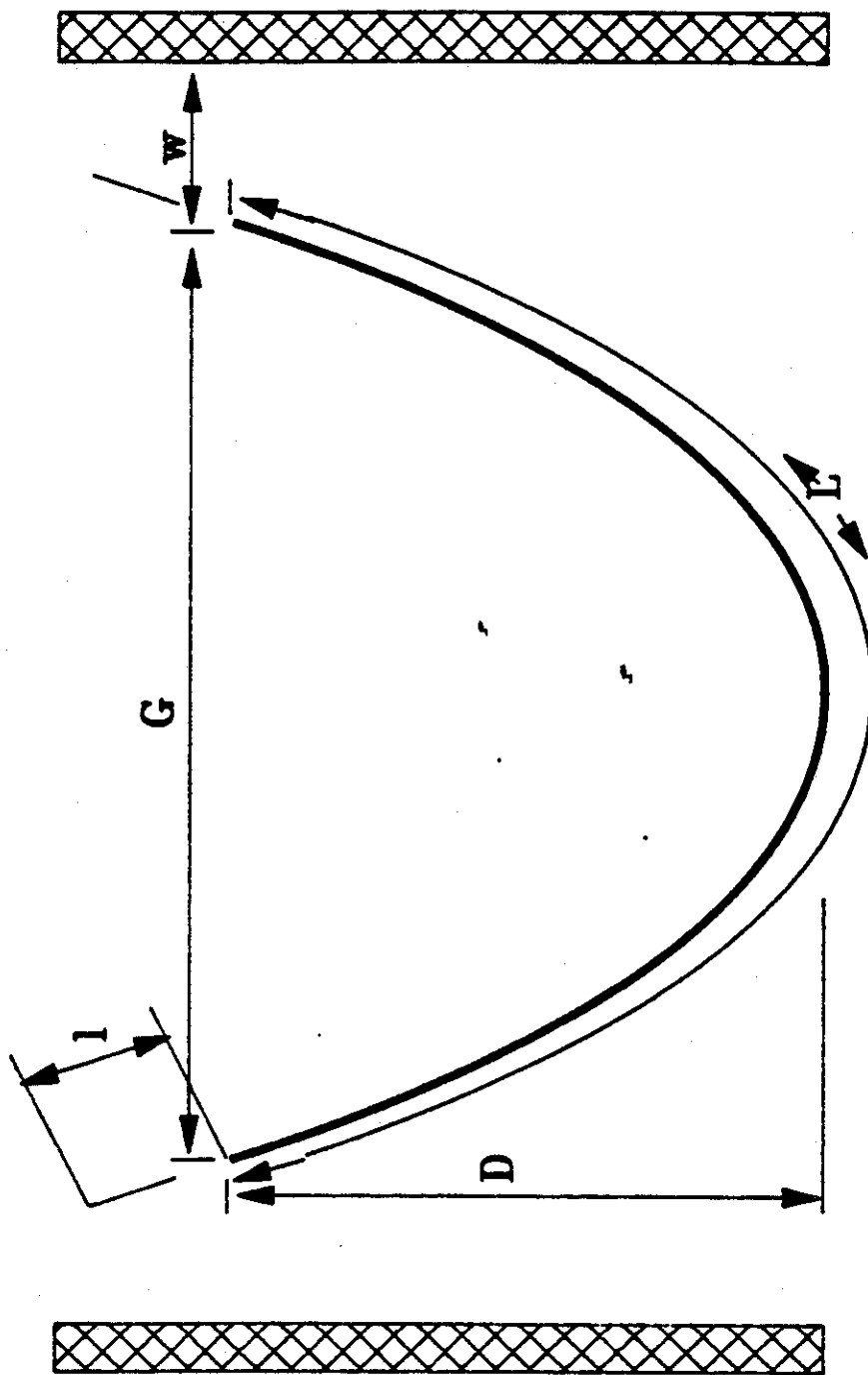
G=Gap = 0.67 L   w= Wall Clearance 2.5d
D = Boom Depth l =leader length = 1.5 to 5.0 m
L = Boom Length 27 - 35 m

Figure 1.   Boom Configuration for tank tests

is greater than 20-kt 10 meters above the tank surface.

5.4.1   Calm-water Critical Tow Speed

Tow the barrier in calm water at 0.5-kt without oil present. After the barrier has formed a catenary, increase the tow speed in 0.5-kt increments until the barrier loses all freeboard (submarines), loses all draft (planes), mechanically fails, or the maximum safe tow speed of the test tank has been reached. Record this speed as the critical tow speed along with the method of failure. Report the critical tow speed as "greater than" in the event of the barrier not reaching the critical tow speed prior to reaching the maximum safe tow speed of the test tank.

5.4.2   Oil Loss Speed Tests

Tow the barrier at 0.25-kt while preloading it with 0.38 cubic meters of test oil. After the oil preload has been distributed and has stabilized at the apex of the barrier, increase the tow speed in 0.1-kt increments. Record as first loss tow speed the speed at which droplets of oil first begin to escape under the barrier. See Figure 2.

Continue to increase the tow speed in 0.1-kt increments until the oil escapes under the barrier in streams. Record as the first-gross-loss tow speed the speed that the streaming loss is first witnessed. Repeat these two oil loss speed tests for Wave
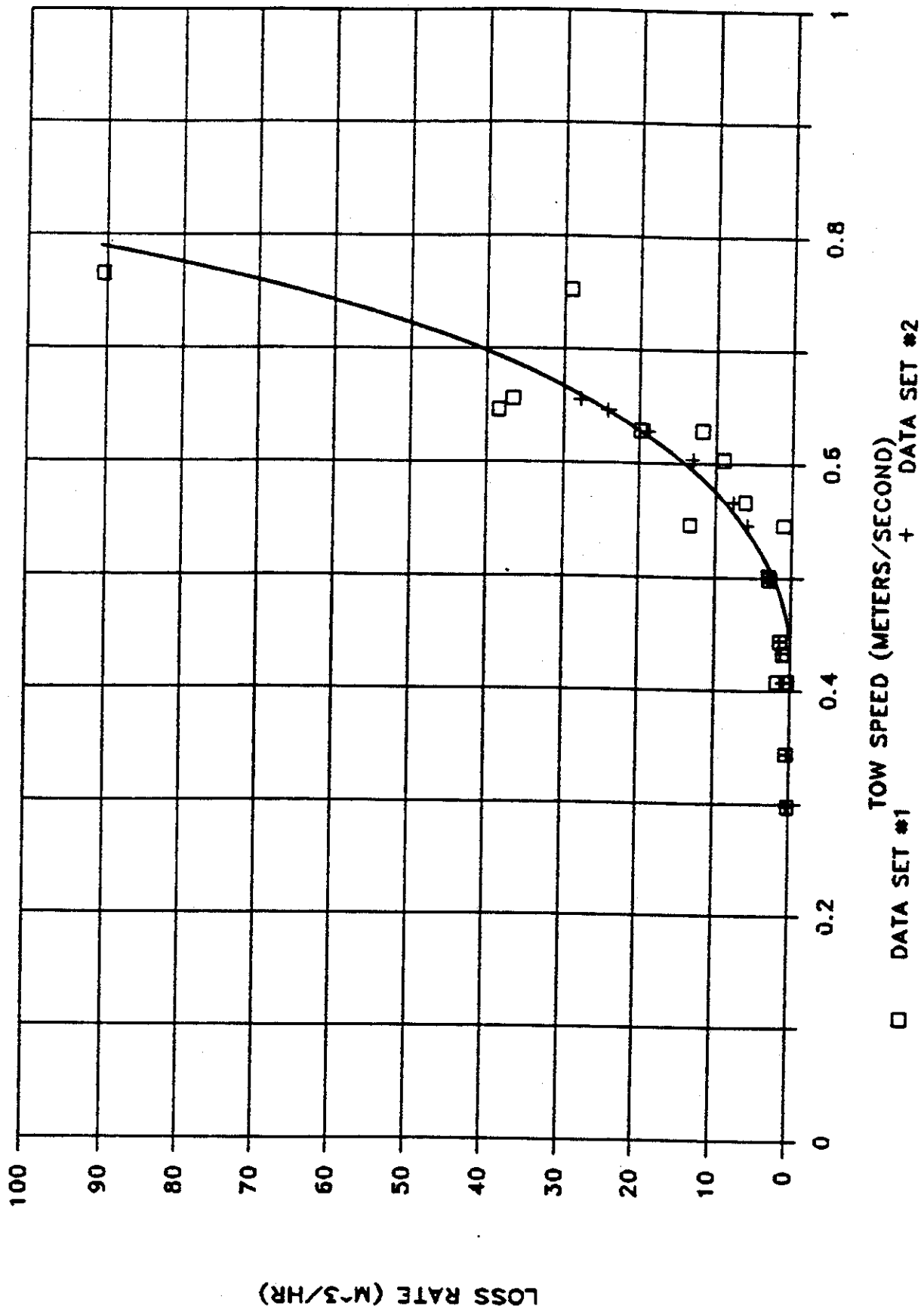
Figure 2. Oil loss rate test results

#1 (breaking regular wave, 5.2.2) and Wave #2 (harbor chop, 5.2.3) surface conditions.

5.5 Oil-loss-rate Test

This test is conducted to quantify the loss rate in calm water.

5.5.1 Test Oil

Use heavy oil as defined in 5.1.2.

The oil will be sampled each time there is an addition to the oil supply. The oil sample will be taken from the bottom of the container holding the oil supply. As a minimum, the oil will be sampled daily. The results of each analysis as presented in Table 1 will be reported. Repeating measurements of the oil viscosity at the tank water temperature is tedious and expensive. Determination of the oil viscosity at an elevated and depressed temperature relative to the expected range of tank water temperatures can save time and unnecessary expense. ASTM STP 341 provides detailed instructions for the log-linear viscosity interpolations. See Figure 3. A composite sample of the water in the test tank will be taken at the start of the testing and at the completion of the testing for analysis of these properties. Average results will be reported.

5.5.2 Test Procedures

The goal of this test is to measure a steady-state oil-loss-
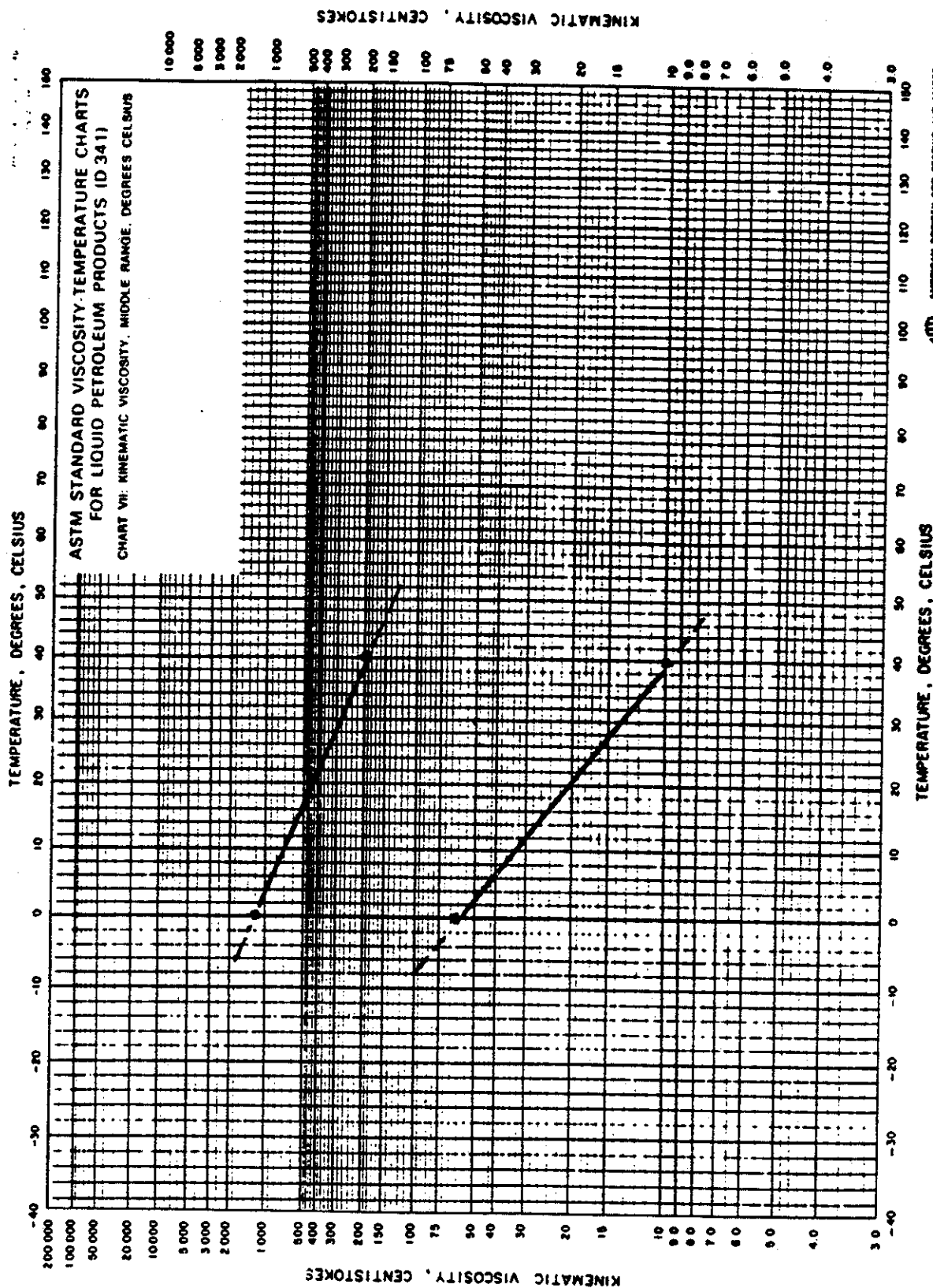
Figure 3. Graphical determination of viscosity

rate. The steady state requires maintaining the quantity of oil in the preload even as the oil is being lost. Anticipated loss rates based on historical data with 30 meter lengths of test boom predict the loss rates are presented in Table 2. This information should be used as a guide; adjustments can be made during testing.

TABLE 2

SPEED	APPROXIMATE LOSS RATE
First loss speed	1.1 M^3/hr
First loss + 0.1 kt	6 M^3/hr
First loss + 0.2 kt	12 M^3/hr
First loss + 0.3 kt	24 M^3/hr
First loss + 0.4 kt	40 M^3/hr

Oil Preloading

Tow the barrier at 0.2-kt less than the first-loss tow speed as determined in 5.4.2 while distributing a preload of 0.19 +/- 0.02m^3 of oil.

After preloading the barrier distribute oil at the rate determined from Table 2. Increase the tow speed from the preloading speed to the designated tow speed when the newly distributed slick first reaches the preload. Continue the test for 3-min of steady state operation then stop distributing oil. Tow at the preloading speed until the last of the newly distributed oil reaches the preload. Carefully use fire hose streams to push the oil lost behind the boom away to be recovered. At the same time

keep the captured oil in the boom area.

5.5.3 Oil-loss-rate Determination

Collect all the oil lost by the boom. This requires capturing, containing and skimming the lost oil. Free water from the skimming activity should be separated from the oil and water emulsion by gravity in a calibrated recovery tank, after draining the free water, and measuring the depth of the remaining fluid, the remaining oil/water mixture is then sampled using a stratified sample thief. See the Appendix "Sampling Stratified Fluids". Using ASTM Method D-1796 determine the quantity of water (% W) from the total stratified sample then calculate the quantity of oil lost where

$$Q = Q_T \; [1- (\%Wx100)]$$

where Q is the volume of oil lost by the booms, and Q_T is the volume of fluid in the recovery tank. The quantity of oil lost by the barrier is divided by the steady state time period to determine the oil loss rate at that tow speed.

Test Unacceptable

An individual test is unacceptable if it shows a difference between oil-loss-rate determined and oil distribution rate of more

than the greater of 0.5 m^3/hr or 5% of the oil distribution rate.

Tow Speeds

Determine oil loss rates at four tow speeds, that span 0.4 kt. above the first loss tow speed. Figure 2, shown earlier, is a graphical presentation of an oil-loss-rate test.

5.6 Indicative Wave Stress Test

Tow the barrier into a harbor chop that has a one-third significant wave height (H) 1/3 = 0.45-m, and a 2.5 to 4-sec period at 0.5-kt until the end of the test tank is encountered. Hold the barrier for 10-min, then tow it to the opposite end of the tank, hold stationary for 10 more minutes. Repeat this process for 45-min of exposure.

During the test, record the booms motion on movie or video tape identifying points of stress. Points to look for include twisting, abrupt tugging or pounding between two elements of the boom, submerging under crests, bridging over troughs, internal floatation members pushing against the outer fabric and other nonfunctional, fatigue producing behavior. Thoroughly examine the boom after the boom is removed from the test tank take photos for documentation.

6.OPEN WATER TEST OF BOOMS

6.1 Scope

This test measures the variation in immersion of an oil spill boom skirt in waves. Measurements are made at two or more points along the boom. The test is intended for booms that would be used in open water (harbor and offshore booms) and provides data that can be used to predict boom failure without spilling oil.

6.2 Summary of the Method

By either mooring or towing a boom in a catenary configuration on a natural sea surface, the depth of the boom skirt will remain constant as long as the boom is conforming to the waves. When the boom is not conforming to the waves, the depth of the skirt will vary in time at any given location along the boom.

Mounting electronic pressure sensors at selected locations permits analog or digital recording of a time based, pressure defined, skirt depth. A trace produced from such data on a 0.9-m high fence boom is shown in Figure 4. The data analysis begins with determining the minimum and maximum immersion. The minimum immersion in Figure 4 is zero which means the skirt came out of the water. The maximum is 0.75-m, which is 0.16-m short of the water splashing over the freeboard.

During an open water test the wave conditions are measured using conventional time based methods. The time based wave height measurements are then transformed to a frequency-height
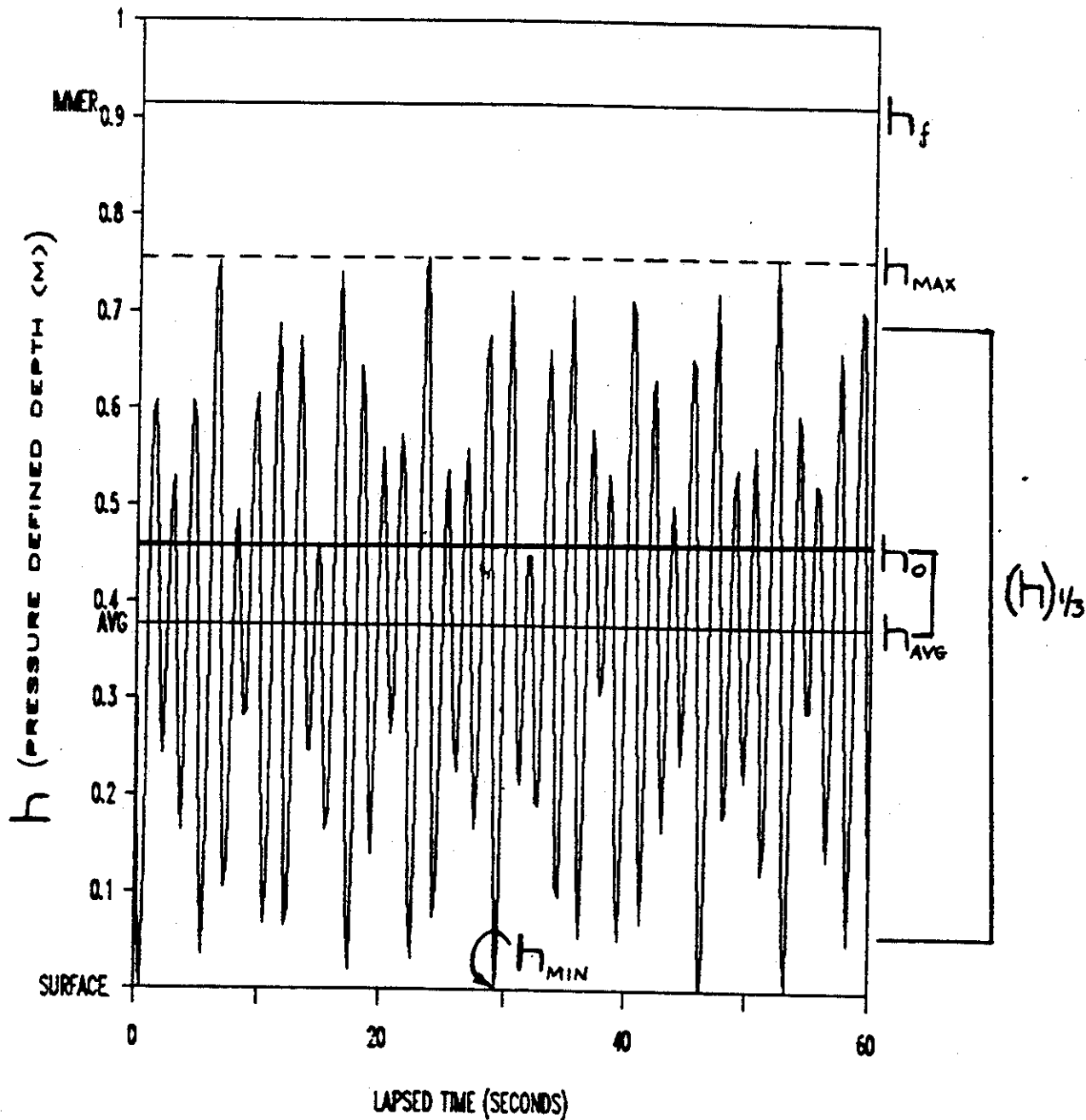
Figure 4. Plot of a boom response with
immersion depth symbols used
in calculations.

relationship by fast Fourier transform (FFT) as shown in Figure 5.

The report consists of the sea spectrum as shown in Figure 6, three boom immersion values and a time based trace of the boom immersion. In addition, current speeds or tow speeds and boom tensions are reported.

6.3 Significance

Data from this open water test can be used to calculate three derived quantities, explained below, called the immersion ratios. These ratios will decrease from 1.0 in calm water to 0.0 in some sea conditions and at 0.0 a boom will not hold oil. At present there is insufficient data to establish a functional relationship between the motion of a boom in waves and oil holding ability. What has been shown is ratios between 1.0 and 0.9 produce little loss in oil holding ability due to waves. Loss of oil holding ability due to waves is significant when corresponding ratios are less than 0.1.

6.4 Site Selection

The wind driven waves desired in the sea surface spectra during open water testing covers the range from 10 second waves at 3 meters to 3.5 second waves at 1.8 meters. A primary consideration in the open-water testing is the selection of a region of
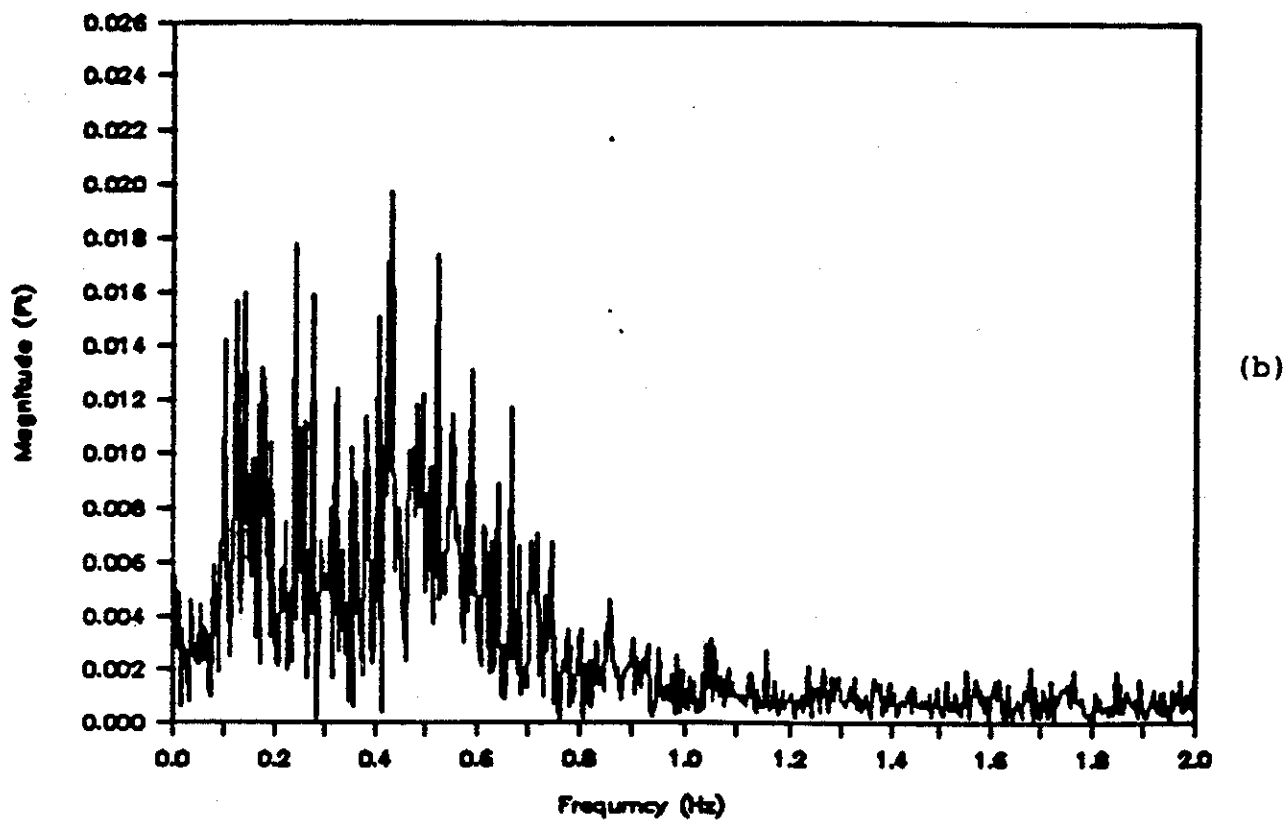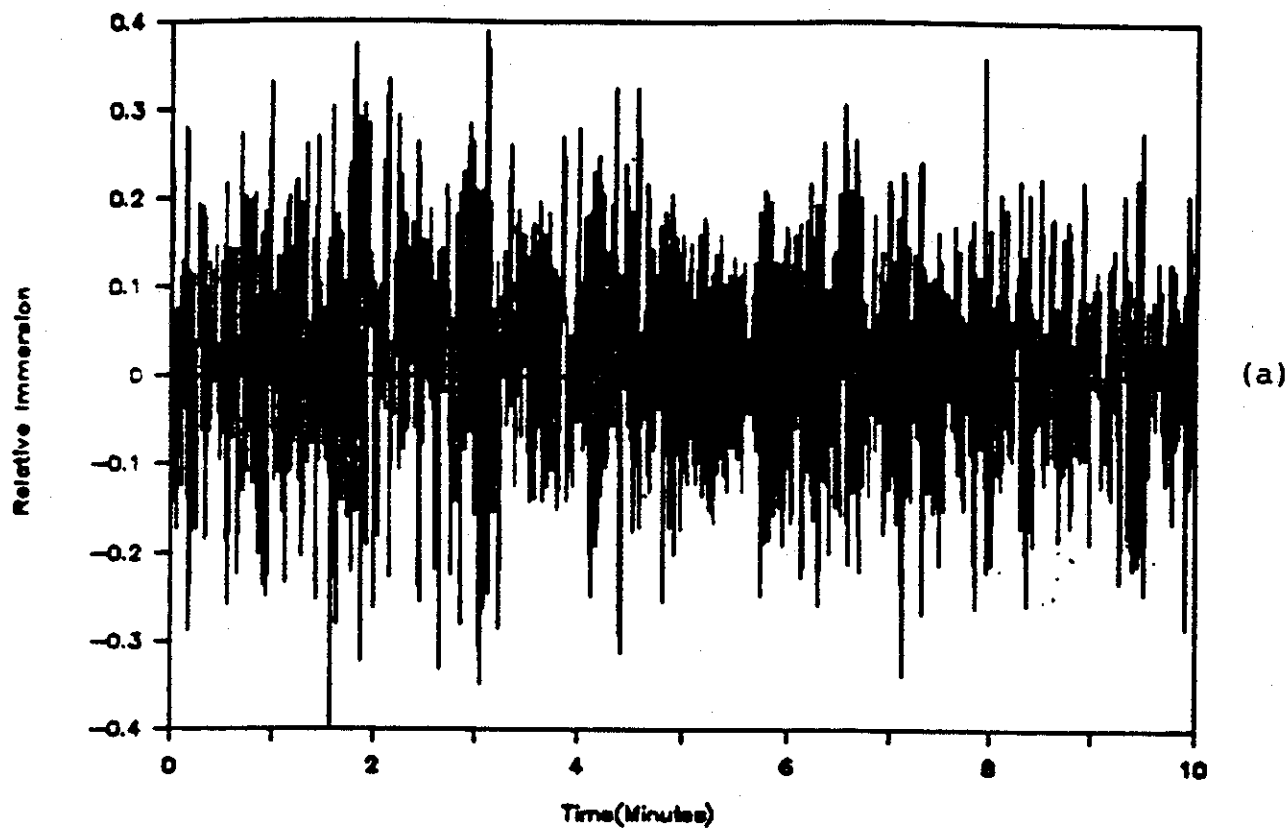
Figure 5. A boom's relative motion in water
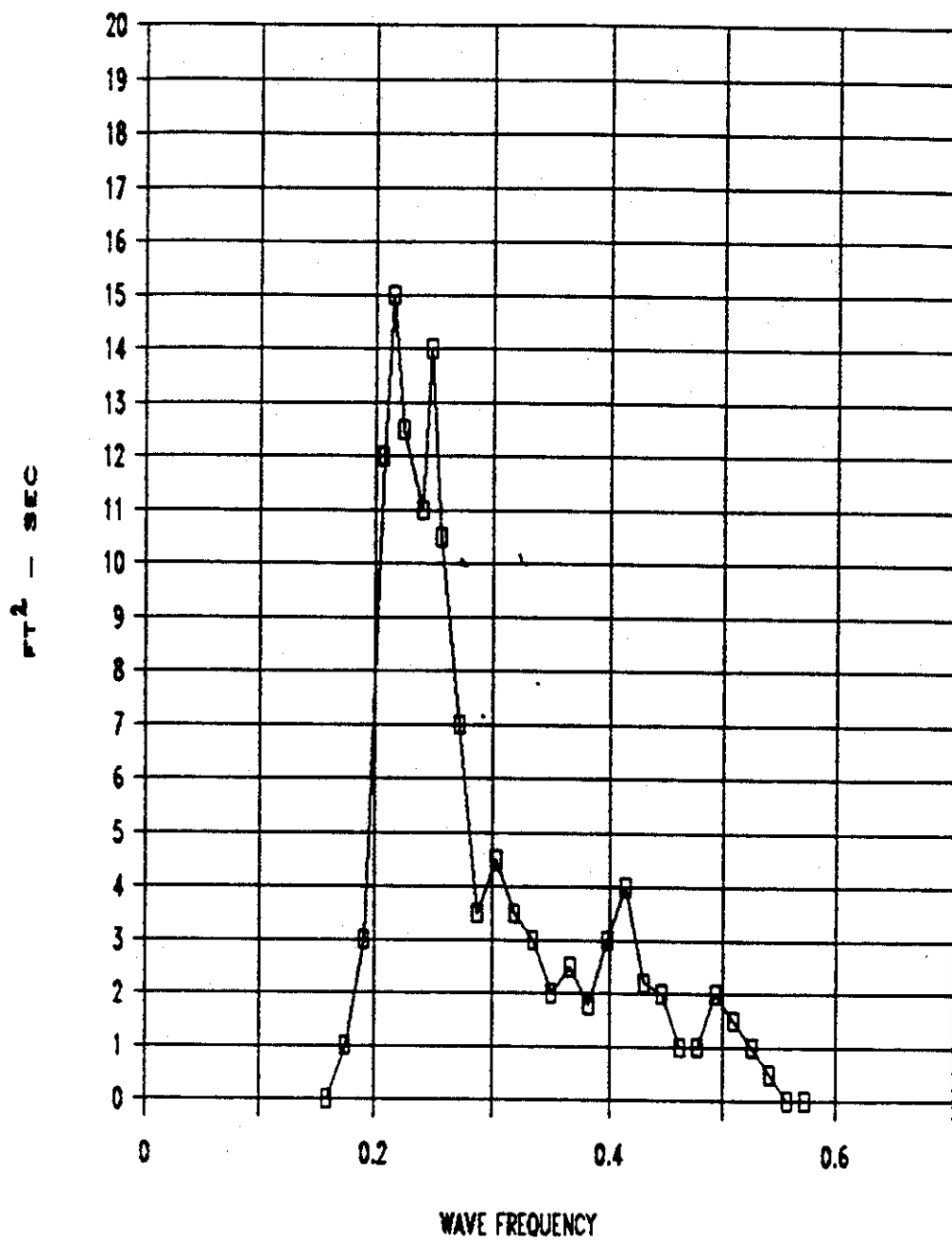(a) time based; (b) frequency based.

Figure 6. Wave spectra for a fully developed
          wind driven sea. Wind speed 24-KT.

open water that has a good probability of providing the designated sea spectrum. The site must be clear of heavily traveled channels; be approved by the Captain of the Port, and not be part of a military test or exclusion zone. In terms of wind conditions to achieve this sea surface the site must provide a 170 mile fetch for a 25 know wind blowing for 16 hours.

6.5 Test Apparatus, Open Water Testing

The test instrumentation consists of the following:

1) At least 122-m of boom

2) At least two submersible +/- 5 psig (+/- 34-kPa) pressure sensors

3) A submersible 5,000 to 10,000 pound (2270 - 4500-Kg) load cell

4) Electronic compass

5) Data cable and/or telemetry system to a recording system

6) Anemometer and wind direction indicator

7) Multichannel analog or digital recorder - data logger to record signals from #1, 2 and 3 above

8) Wave staff or Wave Rider[R] with required auxiliary equipment to measure the sea surface between .1 meter, 0.5 second waves to 4.5 meter 10 second waves. The wave data must be sufficient to calculate a wave amplitude - frequency spectrum.

9) Two 3,900-kg sinkers or two tow vessels that can pull the

boom and maintain way.

10) Stationary tests will need (2) 450-kg net buoyancy mooring buoys; 7/16-in 7 x 16 IWRC steel cable for a 4.5:1 scope; (2) 55-kg net buoyancy floats

11) Video/movie and still cameras

12) Two ruggid hul inflatable boats to help in the rigging

13) A large diployment vessel such as an oil field work boat, 85 to 125 feet

6.6 Preparation of the Apparatus/Calibration

Before mounting any of the instruments on the boom, perform a calibration of the entire measurement system. The pressure sensors and load cell(s) should have response and output signals that equal the characteristics listed in Table 6.1.

TABLE 6.1 Boom Instrumented Characteristics

	MEASUREMENT RANGE	OUTPUT	98% RESPONSE AT
Pressure Sensor	0-5psi	4-20ma*	4Hz
Load Cell	0-10,000 lbs.	0-10 VDC	2Hz
DATA RECORDING Computer	20-90% of 0-2046 BCD's		
Stripchart (Multi Range)	20-90% of a 4" Chart		4Hz

* A low impedance loop is highly recommended for the long cable lengths associated with the pressure sensors. Conversion to a voltage signal using precision resistors at the recording unit. A 62.5 OHM resistor would result in a 0.25-1.25 VDC output.

Calibrate the load cell. Use either the manufacturer or a reliable test and evaluation laboratory.

The pressure sensors can be calibrated in a static column of water. Measure the density of the water to 0.005 grams/cm^3. Using the data recording system record pressure readings at zero immersion, half boom draft, boom draft, and full boom immersion depths. Record these depths with the corresponding pressure reading. Determine the calibration factor $(Kc(PPx^{Kc=hPc})$. During testing the calibration factor (K_T) for pressure reading to boom immersion is calculated using the density of the water (at the temperature during testing) is measured.

$$K_T = \underline{\frac{Kc \times \text{density of Calibration Water}}{\text{density of test water}}}$$

Once calibrated mount the pressure sensors and connecting data cables. The sensor should be 25-mm from the bottom of the solid section. Take pressure measurements at, as a minimum, two positions on the boom. One of the positions must be at or near the apex of the boom. Mark the boom at each data station so that the position of the station along the boom length will be obvious in

the visual record. The data cables should be mounted so normal boom motion is restricted as little as possible. Once the pressure sensors and cables are attached to the boom, carefully pack the boom for shipment to, and deployment at, the test location.

For stationary testing moor the barrier from its end connectors so that the barrier gap equals 67% of the barrier length when the barrier is at the ideal orientation (waves directly into the mouth of the catenary).

The mooring system consists of 3,900-kg concrete sinkers and 450-kg net buoyancy mooring buoys joined with 7/16-in diameter 7 x 16 IWRC steel cable at 4.5:1 scope. The barrier is joined to the mooring buoy with 9-m of the same cable supported at the midpoint with 55-kg net buoyancy floats. The sinkers are positioned using triangulation from three geodetically fixed points on shore. The sinkers are oriented so that a line joining the sinker is perpendicular to the direction of the anticipated predominant wind direction. The water depth is a minimum of 12 meters. See Figure 7.

Information on the water depth at specific locations can be found on NOAA nautical charts. Tide tables are published with sunrise/sunset data by the Department of Commerce. Near-Shore current tables are available, published by NOAA. Climatological studies are available from Sea Grant institutions in the area. Local fishermen can provide general information as to weather

PRESSURE SENSORS
(Two or more)

LOAD CELL

DATA BUOY

MOORING BUOY
or
TOW VESSELS with DATA
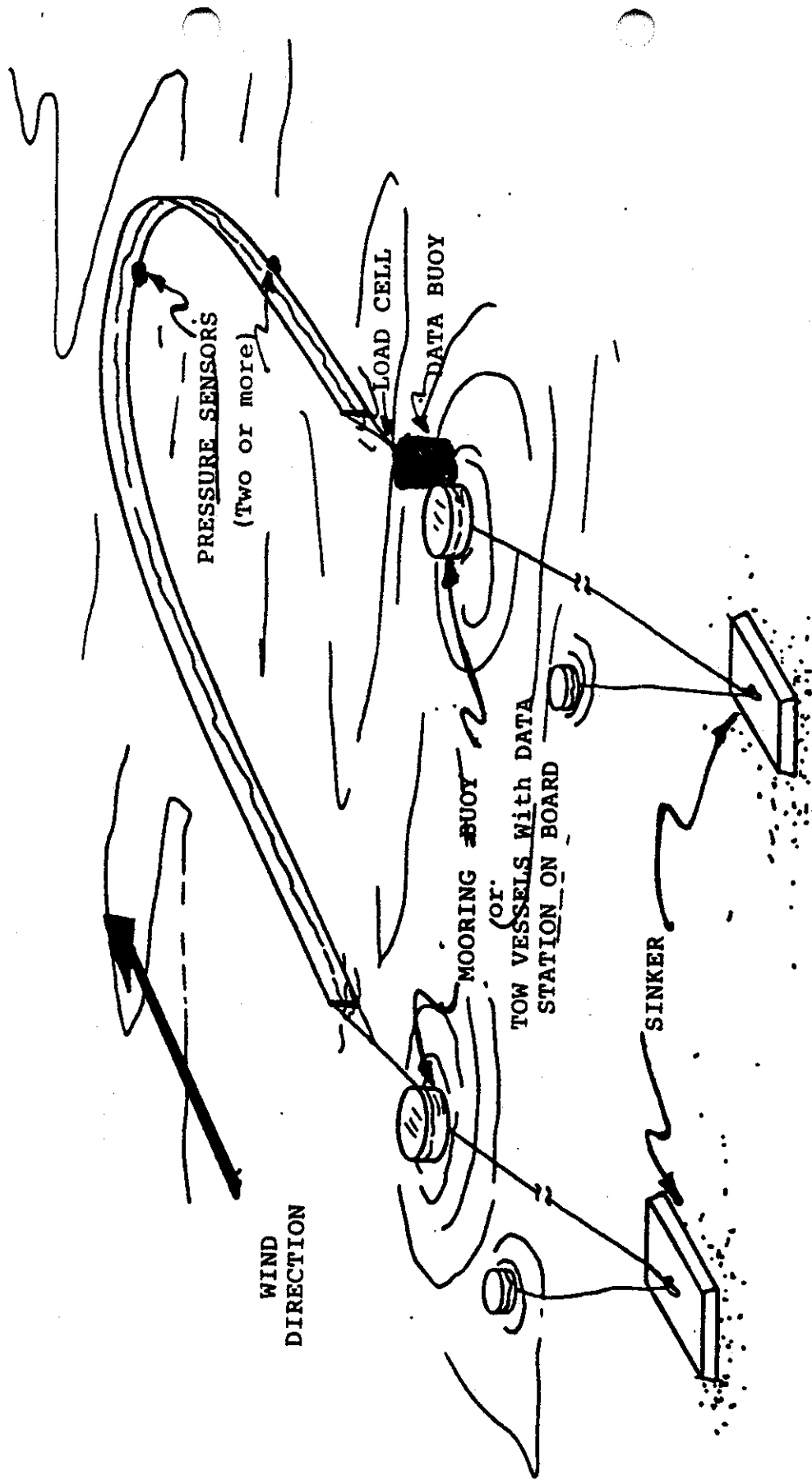STATION ON BOARD

WIND
DIRECTION

SINKER

Figure 7. Boom configuration for open water tests

conditions in various months. Many government agencies routinely record weather conditions on a periodic basis (airports, harbor masters, U.S. Coast Guard, U.S.Navy, are a few). When choosing a site, it is wise to remember that wave size is dependent on fetch (the distance over water to nearest land mass) and to a lesser degree water depth. A stationary configuration allows a reasonably long test duration at low expense. However, there is no control over the catenary alignment with respect to the wind direction.

An alternative is to conduct a tow test. The expense for the tow vessels generally prohibits long duration tests and therefore the desired sea spectrum is less likely to occur. If tow tests are desired the boom configuration would be the same as for stationary tests. Boats would replace the mooring apparatus, and the electronic data acquisition could be done on board one or both of the boats.

6.7 Wave Conformance Test

This test determines a immersion to draft ratio for a boom in the sea spectra existing during the test. The ratio of how the boom maintains its calm water draft in waves is the measure of wave conformance. This behavior is affected by the sea state, wind blowing on the freeboard, surface currents, boom orientation and boom tension. Data outputs from instruments on the boom are:

pressure (that defines the booms immersion), and boom tension. Boom orientation can be measured with an electronic compass. The sea surface (wave spectra) is measured by either a Wave Rider Buoy[R] or wave staff capable of measuring .1 meter waves at 0.4 to 1.0 second periods up to 4.5 meter waves at 10 second periods. Wind speed and direction are measured at the test site during the test. Water surface current speed and direction are measured using a cross T float and stop watch. A cross T float is two 2/4's each 2 feet long, mortised at their centers and joined to form a 2-ft x 2-ft tee. In the case of a tow test a current meter attached to the towing assembly is recommended.

6.7.1 Data Recording

There are two data recording methods. The most useful method is to use electronic sensors to measure all the parameters and digitally log all the information for subsequent computer manipulation. Make digital records 4 times per second for waves and boom immersion. Wave measurements must be recorded this way to permit a spectral analysis of the polychromatic sea surface. Optionally, the dynamic boom measurements (pressure and tension) can be recorded on a stripchart. Spectral analysis becomes more difficult with data recorded this way but the booms immersion or lack of immersion in the sea state is immediately obvious (See the Appendix Measuring Boom Wave Conformance). Record wind speed and direction (3 meters above the water surface) and boom orien-

tation at the beginning, middle and end of each test period. Two tests (duplicate runs) are run sequentially with no more than two minutes between runs.

Digitally logged data requires 2048 data points for each parameter. This represents an 8.5 minute test. Duplicate tests will be run within a 19 minute time period. Videotape the barrier during data logging.

6.8 Durability Test

The booms durability is an empirical assessment of the booms condition before, during and after the open water tests. Take photographs before, during and after the test. Also record evaluations made by on-scene observers paying particular attention to twisting, abrupt tugging of pounding between two elements of the boom, submerging under crests, bridging over troughs internal floatation members pushing against the outer fabric and obvious wear.

7. Calculations

7.1 Oil Loss Rate

The oil loss rate ($\dot{Q}$) is calculated from the percent water in oil value (% W) of the stratified samples, the total volume of fluid recovered (Q_T) and the elapsed time during steady state oil

loss (T)

$$\dot{Q} = Q_T \frac{[1-(\% \ W \times 100)]}{T}$$

T is in minutes and Q_T is in cubic meters.

7.2 Boom Wave Conformance Ratio should be calculated for each pressure sensor. The boom wave conformance ratio (WCR) is the ratio of the average displacements of the boom at the pressure sensor location to the calm water depth. The averaging is done on N displacements over the 8.5 minutes of testing. In a monochromatic constant amplitude wave form the (WCR) equals one half of the peak-to-peak pressure defined depth divided by the calm water draft

$$WCR_f = \left(h_o - 1/2 \ (h_i - h_{i+i}) \right)/h_o$$

Therefore, calculation of WCR from monochromatic tank waves is very straight forward. In a real sea spectrum the waves are polychromatic and because of phase relations vary in amplitude over time. According to the principle of superposition used extensively in wave studies, the total wave conformance ratio WCR_T is equal to the sum of the individual WCR's for each forcing frequency in the sea spectrum

$$WCR_T = WCR_{f1} + WCR_{f2} + \ldots$$

The pressure defined immersion data is treated like a wave, and a 1/3 significant boom wave height $(h)_T{}^{1/3}$ is determined from the stripchart readings and used to calculate WCR_T.

$$WCR_T = \left(h_o - 1/2\ (h)_T{}^{1/3}\right)/h_o$$

7.3   Minimum immersion to draft ratio (I/D).   Refer to Figure 4

$$\frac{I}{D} = \frac{P_{min}}{P_o} = \frac{h_{min}}{H_o}$$

where P_{min} is the lowest pressure recorded by the pressure sensor over the test interval, P_o is the pressure recorded at rest in calm water, h_{min} and h_o are the calculated depths. The frequency of minimum immersion, expressed in min^{-1}, is counted for P within 5% of P_{min}.

7.4   Maximum freeboard immersion to freeboard ration (f/F)

$$\frac{P_f}{F} = \frac{P_t - P_{max}}{P_f - P_o} = \frac{h_f - h_{max}}{hf - h_o}$$

Refer to Figure 4. The frequency of maximum freeboard immersion is counted for P or h within 5% of P_{max} or h_{max}.

7.5 Average Draft Difference Ratio

The difference between the booms calm water rest draft (P_O or h_O) and the average posture of the boom during the open water test (Pave or Have) is calculated as a ratio

$$\frac{P_O - P_{ave}}{P_O} = \frac{h_O - h_{ave}}{h_O}$$

8. Report

8.1 Tank Tests

Wave tank test facility/capabilities

Test date(s)

Test fluid data as in Table 1 fore each required sample

    Salinity

    Specific gravity

    Surface tension

    Interfacial tension

    Viscosity

    Bottom solids and water

Boom Description

    Manufacturer

Length

Draft

Freeboard

Fence or curtain type boom

Net buoyancy

Critical tow speed

First loss tow speeds

Gross loss tow speeds

Oil loss rate (graph, speed vs rate and table)

Time based wave data graphs, one-third significant wave height and wave

period printed on the graph

Text on the wave stress test

8.2 Open Water Tests

The following information is required for a report of an open water test:

Boom Description

Manufacturer

Length

Draft

Freeboard

Fence or curtain type

Net buoyancy

Test Location

Mooring or towing configuration

Test date(s)

Wave data plots

 Time based wave height graph

 Frequency based wave height graph

 Energy spectra graph

Environmental Conditions

 Wind speed, direction, and duration

 Current velocity or tow speed

 Temperature

 Water densit

Immersion ratios

 Minimum immersion to draft ratio and frequency of occurance

 Maximum freeboard immersion to freeboard ratio and frequency

 of occurance

 Wave conformance ratio

Text with photos to document the durability of the boom

9. Precision and Accuracy

MEASUREMENT	PRECISION	ACCURACY
Bottom solids & water	0.0001g	0.0005g
Oil distribution	$0.05M^3$/HR	$0.3 M^3$/HR
Pressure	1.4-mm	6-mm
Salinity	0.1 o/oo	0.1 o/oo
Specific gravity, density	0.0001	0.0002
Surface tension	0.05 Dyne/CM	0.1 Dyne/CM
Temperature	0.1°C	0.1°C
Time	0.01 sec	0.25 sec
Tow, current speeds		
Tank	0.05-KT	0.1-KT
Open Water	0-2-KT	0.5-KT
Tow force	10#	20#
Viscosity	5-CTS	10-CTS
Wave meter		
Tank	1.4-MM	6-MM
Open water	10-MM	10-MM
Wind direction	2°	5°
Wind speed	0.5-KT	3-KT

GLOSSARY

Barrier, Boom

any floating mechanical device intended to prevent the spread of floating oil, increase the thickness of floating oil, or divert the flow of floating oil.

Test Tank

a wave tank which can create a relative velocity between a boom and the water surface.

Tow Speed

the relative speed difference between a barrier and the water in which the barrier is floating. In this protocol "current speed" is equivalent.

Preload

during testing, the quantity of oil distributed in front of and contained by the barrier prior to the onset of oil loss.

Barrier Apex

the portion of the barrier which is farthest from the barrier tow points when towed in symmetric catenary.

Barrier Draft

the maximum distance below the calm-water surface of any boom segment not part of the towing assembly or connector. (D)

Barrier Freeboard

the vertical height of the barrier above the water line in calm water. (F)

Harbor Chop

an irregular condition of the water surface produced by an interference pattern of waves. This is also known as random sea.

Barrier Depth

The perpendicular distance from an imaginary line between the barrier tow points to the apex.

Significant Height

When measuring waves, an average of the highest one half, one third or one tenth are used to characterize the sea surface. The "one third significant wave height" is commonly used.

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